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India's Nuclear Power Journey: Why has it Grown in Fits and Starts?

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On February 22, 2024, PM Modi dedicated units 3 and 4 of the Kakrapar Atomic Power Station (KAPS) to the nation. The construction of both units had started in November 2010 with a plan to complete it in five years. Eventually, it took double that time for KAPS 3 to go critical on July 22, 2020. It took another three years for some commissioning issues to be sorted out. Unit 4 achieved criticality on December 17, 2023 and was connected to the power grid just two days before the PM's latest visit.

At 700 MWe capacity, KAPS 3 and 4 are the scaled-up versions of earlier variants of CANDU pressurised heavy water reactors (PHWRs) that India first built with Canadian help. Having graduated from the two 540 MWe that India had upscaled in the 2000s from the 220 MWe, they are currently the largest capacity reactors that India has indigenously designed and built. With these two, India now has 24 operational nuclear reactors with a total capacity of 8,180 MWe.

The target now is to get to 22,480 MWe by the start of the next decade. Nuclear Power Corporation of India Ltd. (NPCIL), currently India's only operator of nuclear reactors, announced in February 2024 that it will add 18 more nuclear reactors to produce another 13,800 MWe of electricity by 2031-32. India wishes to avail advantages of economies of scale by standardising the design of 700 MWe capacity reactors for 'fleet construction'. Ten of these have already been sanctioned to be built at Gorakhpur in Haryana, Kaiga in Karnataka, Chutka in MP and Mahi Banswara in Rajasthan and are at various stages of construction.

Will India be able to achieve these targets? Will these plants come up as expected, with one new plant being commissioned every year, as was announced by the Minister in charge of atomic energy at the start of this decade? Scepticism is natural given the experience in India of the long gestation of nuclear plants. On many occasions, ambitious targets have had to be revised. Why has India missed targets so often? Why has the perception grown that India's nuclear power potential is over-promised but under-achieved?

Factors Responsible for the Fits and Starts

Early Initiation into Nuclear Energy

The Indian nuclear programme was amongst the first high-end science and technology efforts to be announced after independence as PM Nehru was laying the foundation of modern India. He had a worthy teammate in Homi J Bhabha, the architect of India's nuclear programme, who had, in fact, written a letter on March 12, 1944, to the trustees of Sir Dorabjee Tata Trust proposing the establishment of an institute to train nuclear scientists. This was even before the use of atomic bombs by the USA. Bhabha expressed his vision thus, "When nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand."[1] Nehru too acknowledged the importance of atomic energy in his Presidential address to the Indian Science Congress in 1947, where he said atomic energy "may be used for war or may be used for peace. We cannot neglect it because it may be used for war… we shall develop it, I hope, in cooperation with the rest of the world and for peaceful purposes."[2] Therefore, the initial focus was to tap the civilian potential of the atom. Accordingly, India legislated the Atomic Energy Act on April 15, 1948, leading to the creation of the Atomic Energy Commission on August 10 of the same year.

It may be recalled that internationally, too, this was the period of nuclear euphoria[3] when people believed that nuclear electricity would be so cheaply produced that it would not require to be metered. US President Eisenhower announced the Atoms for Peace programme in 1953, whereunder the USA entered into nuclear cooperation agreements with many countries. This proved to be timely for India, as was Bhabha's chairmanship of the International Conference on Peaceful Uses of Nuclear Energy in 1955. In his opening address, he highlighted the importance of this energy for developing nations: "For the full industrialization of the underdeveloped countries and for the

continuance of our civilization and its further development, *atomic energy is not merely an aid, it is an absolute necessity*."[4]

Making use of his contacts abroad, Bhabha secured nuclear cooperation for India from a number of sources. In June 1954, he requested Sir John Cockroft, his colleague from Cambridge and an important figure in the British atomic programme, to help India build a low-power research reactor. 'Apsara,' a research reactor that he designed with initial fuel from the UK, went critical in August 1956. The second research reactor to attain criticality, in 1960, was CIRUS–a 40 MW reactor built with Canadian help and with the heavy water supplied by USA. Canada also helped India set up its first power reactor, a PHWR, at Rawat Bhatta in Rajasthan. Meanwhile, the US helped India construct two 200 MWe (later 160 MWe) boiling water reactors (BWRs) at Tarapur. Built through a turnkey project, Tarapur Atomic Power Stations (TAPS) went critical in 1969 and provided India with valuable reactor construction and operating expertise, besides electricity to the grid.

It should also be mentioned that Bhabha had conceptualised a three-stage plan for India's nuclear energy trajectory. After the first phase of construction of PHWRs, he planned the second phase with fast breeder reactors and then the third stage of thorium utilisation. The details of this plan and its relevance in today's times will be discussed in a future column, but suffice it to say that India's investment in nuclear energy was with a clear blueprint in mind. Nuclear energy was seen as a long-term commitment to achieve energy self-sufficiency.

First Shock of 1974

The plans, however, began to look shaky once India conducted a peaceful nuclear explosion (PNE) in 1974. Washington perceived this as a betrayal of trust by India, for it had used the heavy water supplied for CIRUS and the plutonium produced therefrom in its nuclear explosive device. Hence, under US laws, it ceased all cooperation with India and also reneged on its contractual obligations to supply enriched uranium to fuel the two power plants at Tarapur. India, however, maintains that it violated no contractual commitments in conducting the PNE since these, during the 1960s and 70s, were considered legitimate civil engineering purposes, with the US and USSR themselves conducting several PNEs. [5]

Notwithstanding this argument, India came under sanctions and was denied access to dual-use technology, the list for which went on expanding through the 1980s and 1990s.

Therefore, India's nuclear power programme was forced, after 1974, to rely on indigenous R&D and domestic industrial efforts. This resulted in time delays and cost overruns for existing projects. Installed capacity in 1979-80 was about 600 MWe, and it could climb to no more than 950 MWe by 1987. In fact, after RAPS 1 went online in 1973, there was a long gap until 1981 when RAPS 2 started commercial power production. Only two other power plants, MAPS 1 and 2 at Madras, became critical in the 1980s. Four more–NAPS 1 and 2 at Narora & KAPS 1 and 2 at Kakrapar–came online in the 1990s. By 2000, the total nuclear energy generation stood at a mere 2,720 MWe.

So, the PNE impacted the pace of India's nuclear power programme by putting a hard stop to ongoing nuclear cooperation and compelling India to rely on its own scientific and technological resources. It brought India onto the nuclear proliferation radar and made it a victim of technology denial regimes, many of which were created as a consequence of the Indian action. Thereafter, the power programme struggled over the next two decades.

Second Shock of 1998

It was only by the second half of the 1990s that the nuclear power programme began to get back on its feet. Indigenous efforts led to the construction of the first 540 MWe nuclear reactor. Overall, seven plants were under construction by 1998. That is when India chose to overtly demonstrate its nuclear weapons capability. Though this time, the pace of work on power reactors remained largely unaffected, constraints on further growth of the programme began to be felt in the early years of the new millennium. These were felt not in nuclear technology, expertise or financing but in the availability of uranium as fuel for an expanding power programme. This challenge, and the desire of the DAE to rapidly enhance nuclear power production through the induction of additional imported, larger capacity power reactors, persuaded the government of the day to explore options for international civilian nuclear cooperation.

A window of opportunity opened when President Bush offered the promise of a constructive nuclear engagement with India. His vision was encapsulated in the joint Indo-US statement of July 18, 2005, signed when Prime Minister Manmohan Singh visited Washington. This was an implicit recognition of India as a rising economic power with substantial energy requirements and as a "responsible state with advanced nuclear technology". Therefore, from being viewed as an outcast to being chastised for "illegal" nuclear weapons possession, the then Indian PM described it in the

Indian Parliament as a step where: "The existence of our strategic programme is being acknowledged even while we are being invited to become a full partner in international civil nuclear energy cooperation".[6]

Nuclear Accident at Fukushima, 2011

It took three years of negotiations between India and the USA to arrive at an agreement on civil nuclear cooperation. Debates within both countries examined the pros and cons of such engagement. Meanwhile, Washington had to amend its own legislation to enable cooperation with India, and New Delhi had to envisage and engage in a separation plan to distance its civil and strategic nuclear programmes. Finally, in 2008, after fixing all the necessary national and international requirements, India and the USA signed the 123 Agreement. Thereafter, the Nuclear Suppliers Group granted a waiver to India to partake in international nuclear commerce.

Between 2008 and 2011, India signed several MOUs with many countries for the import of uranium as nuclear fuel and also for the construction of large-capacity imported nuclear reactors. Nuclear enthusiasm and dreams of rapid reactor expansion soared, only to be dashed by an accident at the Fukushima nuclear power plants in Japan in 2011. This cast a pall of gloom on nuclear energy programmes worldwide. Concerns about nuclear safety compelled governments to institute safety reviews and scale back expansion plans. India, too, became a victim of this even as it was getting ready to take steps towards opening up its nuclear sector to entry of domestic and international private players.

Nuclear Liability Law, 2011

Fukushima brought attention to civil liability in case of an accident. In the case of India, the NPCIL, created in 1986, had been the sole designer, constructor and operator of all nuclear reactors in India. Accordingly, the liability rested with the government of India. But, as the prospects of entry of private players into the field grew after 2008, it became necessary to enact the required legislation. Influenced by the experience of Fukushima, as also by that of the Bhopal Gas tragedy of 1984, when an accident in a gas plant run by an American company, Union Carbide, had led to the death of 20,000 people, the government drafted a stringent Civil Liability for Nuclear Damages Act (CLNDA). In fact, at the time that the Act was being debated in India, the verdict for the Bhopal gas leak accident was announced, and the public mood was critical of the inordinate delay in providing

compensation to the victims and the inadequacy of the compensation amount. Therefore, the opposition parties then insisted on a strong nuclear liability law.

As it came into being, the CLNDA made both the suppliers and operators liable in case of an accident. While this was done to assuage public concerns, it was seen as a harsh move by the private industry, and it turned away prospective nuclear suppliers from wanting to invest in the nuclear sector. Subsequently, to reassure the suppliers that they would not be held liable and that the NPCIL as operator would be the one in charge, the government provided clarifications through a special notification in 2015. In 2016, it also set up an insurance pool to facilitate confidence by covering suppliers' risk. A special Nuclear Liability Fund of Rs 2000 Crores was created to cover damages resulting from a nuclear accident in case they exceeded the limit specified at Rs 1500 Crores for nuclear power operators under the CLNDA. However, private participation in the construction and operation of nuclear reactors in India has yet to see the light of the day. While private industry has long been engaged in supplying equipment to the NPCIL, the hope of their teaming up with NPCIL for a partnership has not yet occurred.

Meanwhile, another public enterprise, the National Thermal Power Corporation (NTPC), did form a Joint Venture Company (JVC) named Anusakthi Vidyut Nigam Limited (ASHVINI) with NPCIL in 2011. Atomic Energy Act was amended in 2015 to enable such joint ventures of Public Sector Units (PSUs) to build, own and operate nuclear power plants in India. Press reports of May 2023 indicated that the JV will build the 2 x 700MW Chutka Madhya Pradesh atomic power project and the Mahi Banswara Rajasthan atomic power project, which has a 4 x 700MW capacity.[7]

Meanwhile, in another attempt to rejuvenate the possibility of private participation, it was reported in February 2024 that India would seek funding from private industries up to the tune of US$ 26 billion to accelerate the nuclear power programme as a way of reaching India's commitment of 50 per cent electricity from non-fossil fuels by 2030.[8] Under the proposed plan, private companies like Tata Power, Reliance Power, Adani Power and Vedanta, will invest in the nuclear plants, acquire land, and undertake construction in areas outside the reactor complex of the plants since the right to build and run the stations and their fuel management will rest with NPCIL. But, the private companies are expected to earn revenue from the power plant's electricity sales and NPCIL would operate the projects for a fee. It remains to be seen whether this hybrid model will receive enough traction from the domestic private industry.

The Future

With more than six decades of operational experience and 24 operating nuclear power plants, India's nuclear establishment has shown its scientific and technological prowess. It is also clear that this experience can come in handy to enable India to meet its climate commitments. The benefit of nuclear energy as a baseload source of low-carbon electricity is unmatchable by the currently popular renewable sources such as solar and wind. But nuclear energy can make a worthwhile contribution to electricity generation only if it can see rapid expansion.

For this, the nuclear sector needs public-private partnerships. This partnership refers not only to NPCIL and private industry but also to a pact of trust between the nuclear establishment and the public. Interestingly, the international mood for providing help to India with nuclear fuel and technology is favourable. Fortunately, India also has the indigenous expertise and engineering experience to make the most of the time. However, domestic outreach to the Indian public is imperative to explain to them the need for nuclear energy as an environmentally friendly source of electricity and the amount of effort put into nuclear safety and security. This could help overcome some of the scepticism.

Several factors are responsible for why the Indian programme has not performed as well as it could have given the early start. This understanding is important to retain faith in this source of electricity generation, whose importance will only grow as climate change concerns require urgent mitigation and a growing economy demands more and more electricity. The value of India's nuclear power programme should not be underestimated despite its low contribution to overall electricity production at this moment. If all things go right, including the operationalisation of the prototype fast breeder reactor that would herald the start of the second stage of its programme, the sector could yet take off. Further discussions on the opportunities and challenges will continue in future issues of this column.

Notes:

[1] HN Sethna, *Atomic Energy* (New Delhi: Publications Division, 1972), p.1.

[2] As quoted by Itty Abraham, *The Making of the Indian Atomic Bomb: Science, Secrecy and the Postcolonial State* (New Delhi: Orient Longman, 1999), p. 47.

[3] For instance David Dietz, an American journalist and Pulitzer prize winner wrote, "With energy as abundant as air we breather, there will be no longer any reason to fight for oil or coal…" in his *Atomic Energy in the Coming Era* (Dodd Mead: 1945) pp. 12-23. Glenn Seaborg , adviser to US Atomic Energy Commission in 1950s too described it as a "magician's potion that could free industrial society permanently from all practical bounds", in Seaborg and William Corliss, *Man and Atom: Building a New World through Nuclear Technology* (Dutton, 1971).

[4] United Nations, *First International Conference on the Peaceful Uses of Atomic Energy* (New York, 1955), vol. 16, p. 33. Emphasis added.

[5] Germany too, in the early 1970s conducted a feasibility study for a project to build a canal from the Mediterranean Sea to the Western Desert of Egypt using nuclear demolition. This project proposed to use 213 devices, with yields of 1 to 1.5 megatons detonated at depths of 100 to 500 m, to build this canal for the purpose of producing hydroelectric power.

[6] PM's statement in Parliament on 27 Feb 2006. Full text available in *The Hindu*, 28 Feb 2006

[7] "NTPC and NPCIL to jointly develop nuclear power plants in India', Power Technology, May 2, 2023. Available at https://www.power-technology.com/news/ntpc-npcil-nuclear-power-plants/. Accessed on Feb 23, 2024.

[8] Read more at: https://economictimes.indiatimes.com/industry/renewables/india-seeks-26-bln-of-private-nuclear-power-investments/articleshow/107848710.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst/. Accessed on Feb 26, 2024.